

Multimedia Risk Assessment of Biodiesel: Relative Mobility, Biodegradation, and Aquatic Toxicity

TR Ginn¹, ML Johnson², KM Scow³, J Miller⁴, L Rastegarzadeh¹, T Hatch¹,
A Epple¹, V Nino¹, T Schetrit¹, T Barkouki¹, D Rice, T McKone⁵

¹ UC Davis Civil & Environmental Engineering

² UC Davis Aquatic Ecosystems Analysis Laboratory

³ UC Davis Department of Land, Air, and Water Resources

⁴ Aquascience Inc., Davis CA

⁵ UC Berkeley, Environmental Health Sciences

**D. Rice,
CUPA 09**

Multimedia Risk Assessment

Tier 1

Tier II

Tier III

Tier 1 Preliminary Review

- Define framework and approach
- Identify information needs and gaps
- Peer review

Tier 2 Multimedia Risk Assessment Design Review

- Experimental design developed and submitted
- Design peer reviewed, feedback provided for Tier 3

- Final report is used as the basis for recommendations submitted to the Environmental Policy Council
- Final report is peer reviewed

Tier 3 Final Multimedia Risk Review

Multimedia Risk Assessment¹

Tier 1

Tier II²

Tier III



¹ <http://www.arb.ca.gov/fuels/multimedia/multimedia.htm>

² <http://www.arb.ca.gov/fuels/diesel/altdiesel/biodiesel.htm>

Multimedia Risk Assessment¹

Tier II²

Results to Date

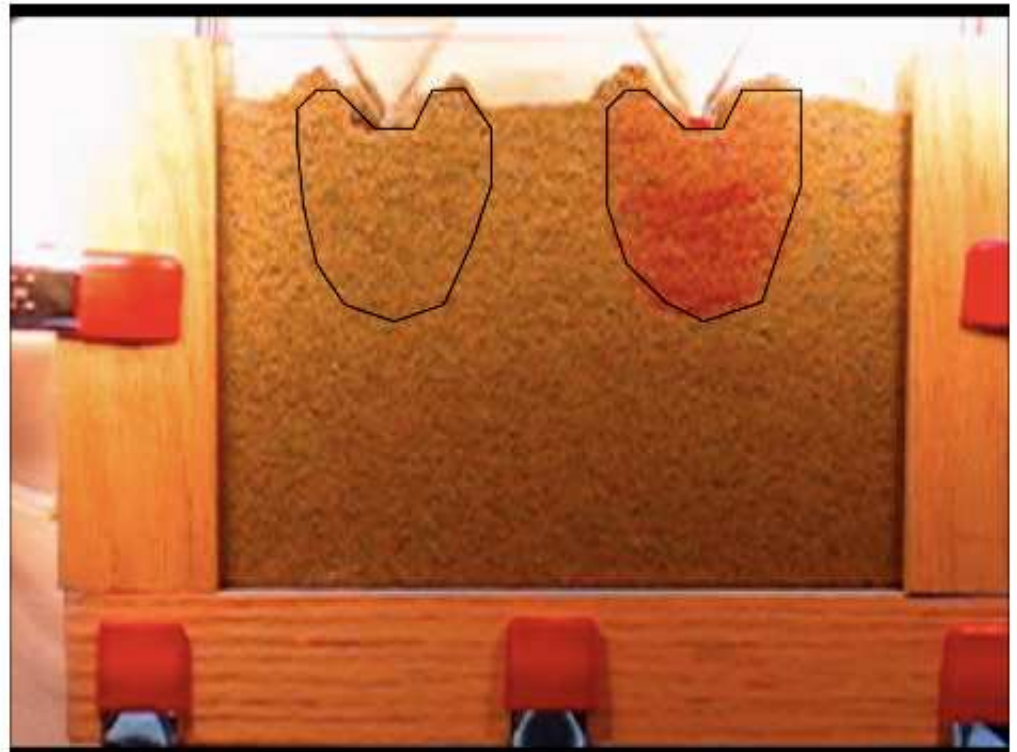
- Mobility
 - Side-by-side infiltration in 2D “ant farm” flow cells
- Biodegradation Tests
 - Microcosm respirometry in soil slurry, 29 day
- Aquatic Toxicity
 - Suite of freshwater/estuarine toxicity tests

¹ <http://www.arb.ca.gov/fuels/multimedia/multimedia.htm>

² <http://www.arb.ca.gov/fuels/diesel/altdiesel/biodiesel.htm>

Mobility

- Image analysis of biodiesel vertical infiltration in “Ant Farm”
- 30x20x2cm, #20 (coarse) sand, water table
- Soy- and Animalfat-based 100% and 20% blends, 1 additive
- “Ant-farm” preparation
 - Wet-pluviated sand
 - Drain to water table
 - simultaneous 40mL CARB#2 and biodiesel side-by-side, both red
- Data collected
 - plume motion in vadose zone
 - lens form & surface area, on water table



Mobility

Soy B20a CARB ULSD#2

Sample Results Final Lenses

- Soy B20 least different

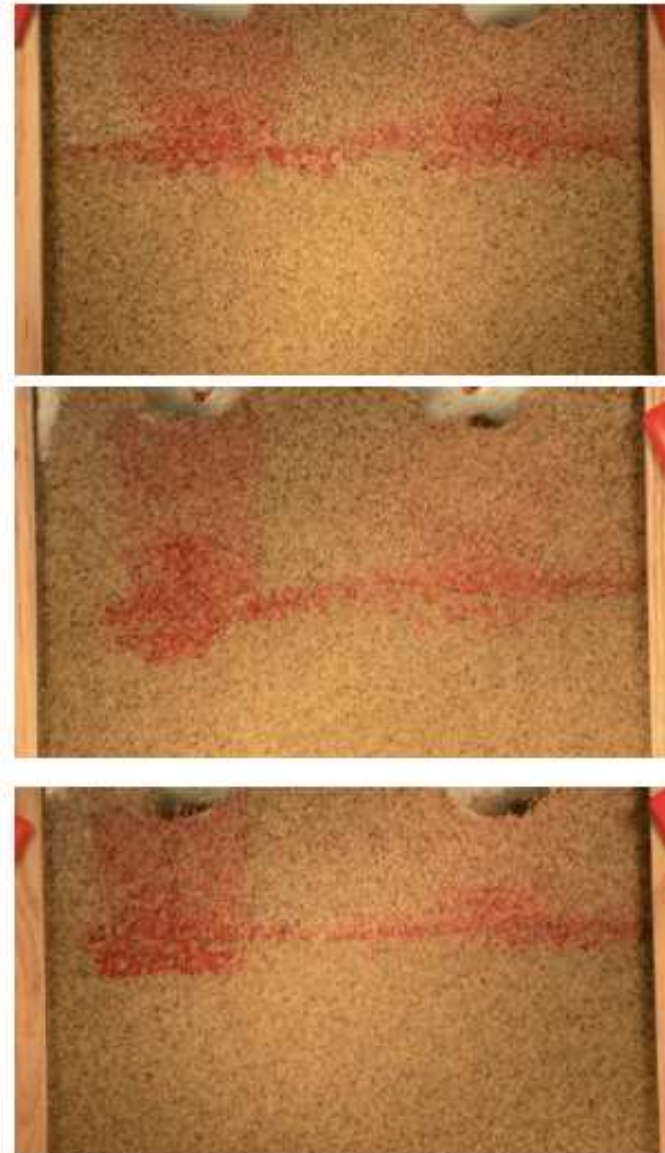


Mobility

AF B100a CARB ULSD#2

Sample Results Final Lenses

- Animalfat B100
strongest effect
 - similar travel times
 - Less lateral dispersion
 - Smaller, deeper lens
 - more residual, less sfc area



Mobility

Summary

- Minor differences in
 - traveltimes
- AFB100a only shows Moderate differences
 - smaller lens formation
 - more residuals

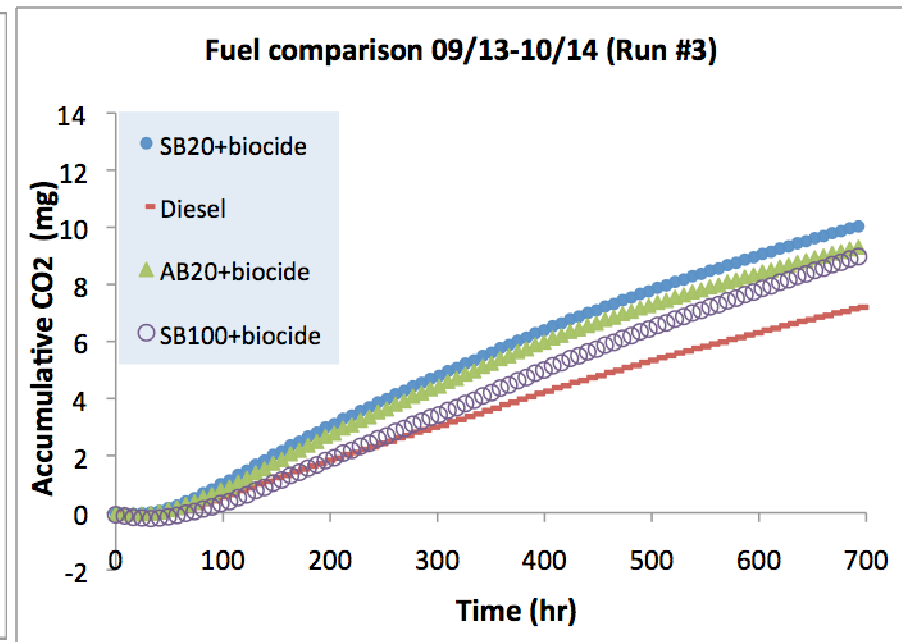
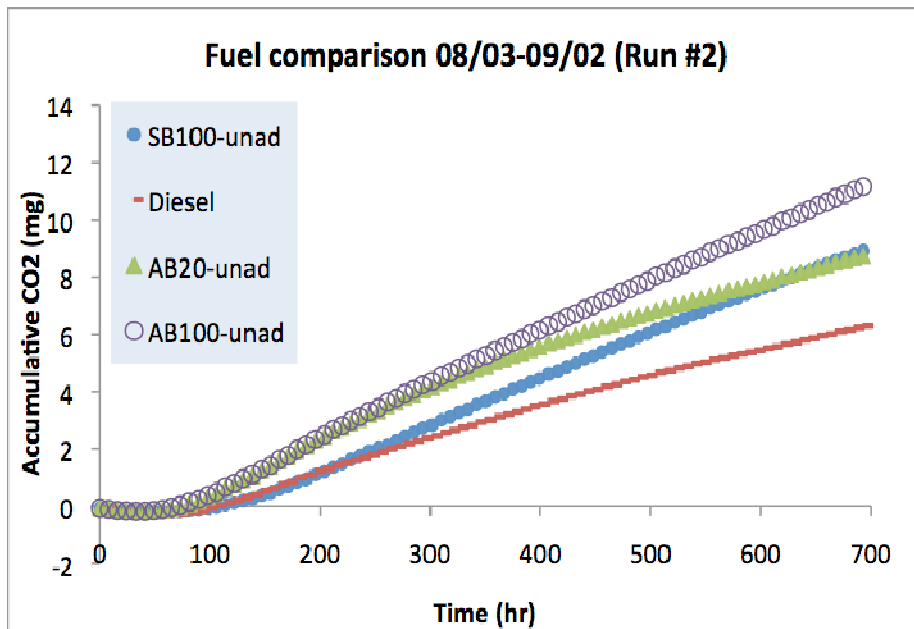
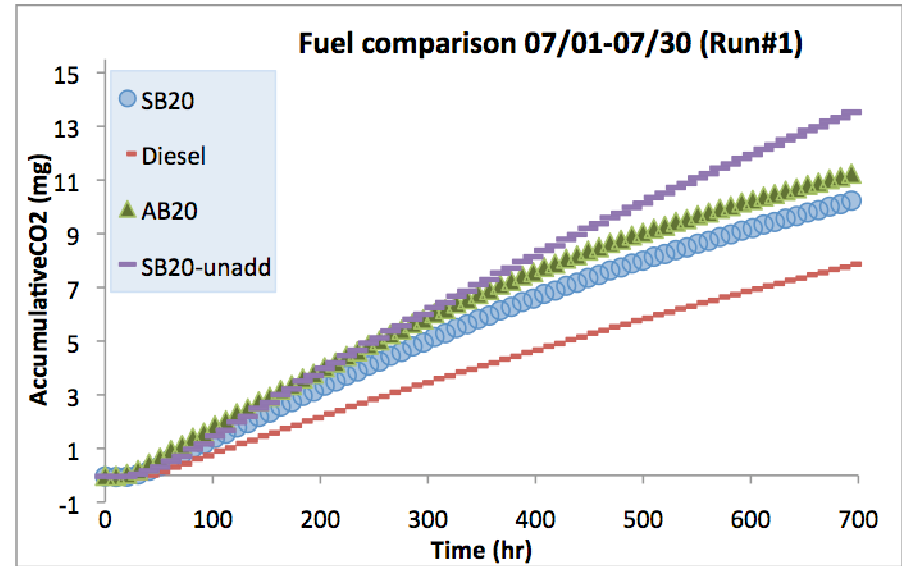
Biodegradation Tests



- 29-day Respirometry using soil slurry inoculum
 - Soy- and Animalfat-based 100% and 20% blends, 2 additives
- Microcosm preparation
 - 250 mL flask that consists of 200 ml mineral medium
 - 2 g soil (Yolo silt loam) as bacterial inoculums
 - 5uL of test substrate
- For each fuel type:
 - triplicate batch
 - one sterilize control (1% sodium azide) - showed no CO₂.

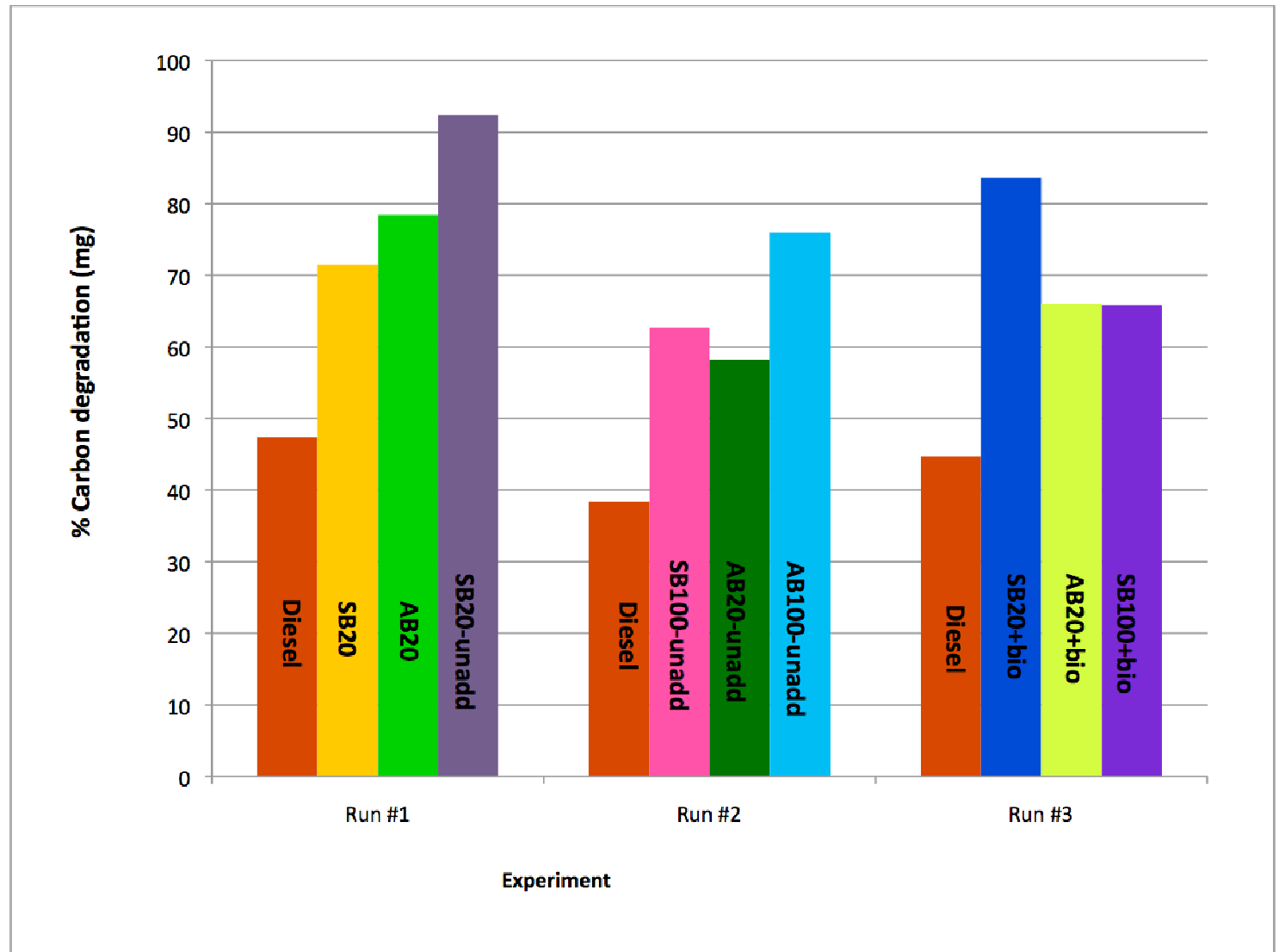
Biodegradation Tests

Example Results



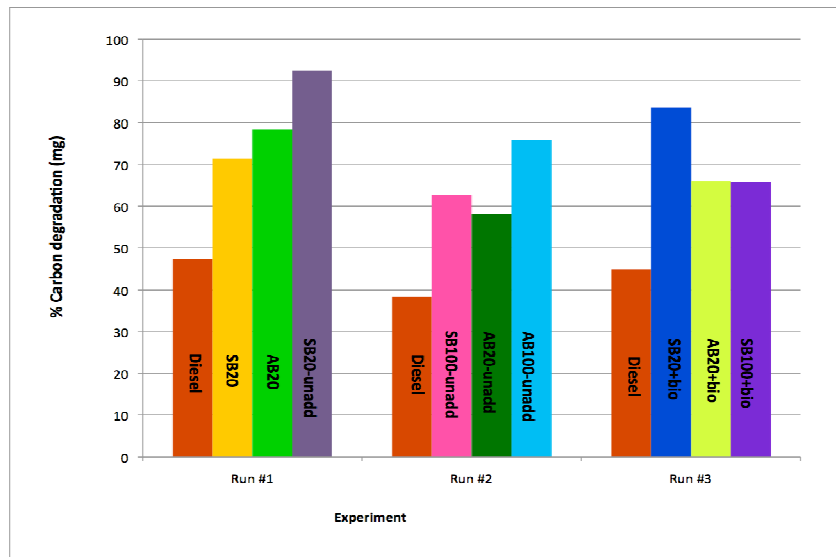
Biodegradation Tests

29Day Cumulative degradation percentages



Biodegradation Tests

Summary



- All fuel blends more readily degradable than ref. fuel
- Soy-based blends somewhat more degradable than Animalfat-based blends
- 20% biodiesel blends somewhat more degradable than 100% biodiesel
- Additives effect are minor

Aquatic Chronic Toxicity Tests



- 6 fuel blends
- 3 freshwater and 3 estuarine organisms
- 6 dilutions plus a control per species/fuel
- Using published USEPA chronic toxicity testing protocols
- “100% solutions” produced using the “slow stir” method, defining equilibrium solubility conditions
- All tests met protocol QA/QC requirements

Aquatic Chronic Toxicity Tests

Details

6 Blends in addition to reference fuel (ULSD)

- Animalfat biodiesel (100% 20%, 20% w/additive)
- Soy biodiesel (100% 20% 20% w/additive)

100% solubility solution by slow stir method

- solutions 100%, 50%, 25%, 10%, 5%, and 1%, w/stock
- # 2 samples/test archived frozen for later analysis
- # Replicates for particular combinations.

Interpolate among dilutions to determine EC_{25}

- **“Toxicity” as $TU = 100/EC_{25}$**

$TU < 1$ no effects

$TU = 1$ effects seen only at 100% solution

$TU = 100$ effects seen at 1% solution

Aquatic Chronic Toxicity Tests

Details

Category	Species	Duration	Endpoint
Freshwater	Green algae (<i>Selenastrum capricornutum</i>)	48-hour	Cell Number
	Water flea (<i>Ceriodaphnia dubia</i>)	7-Day	Survival and Reproduction
	Fathead Minnow (<i>Pimephales promelas</i>)	7-Day	Survival and Growth
Estuarine/Marine	Abalone (<i>Haliotis rufescens</i>)	48-Hour	Shell Development
	Mysid shrimp (<i>Mysidopsis bahia</i>)	7-Day	Survival and Growth
	Topsmelt (<i>Atherinops affinis</i>)	7-Day	Survival and Growth

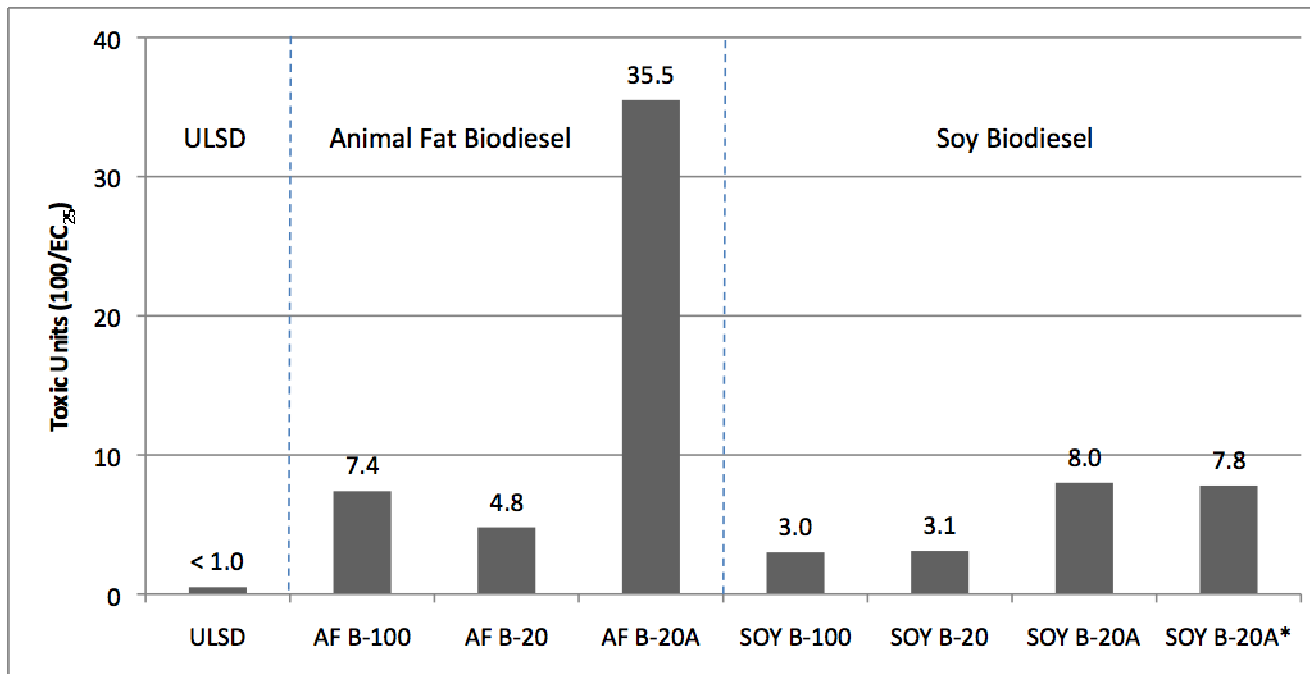
Aquatic Chronic Toxicity Tests

Results

- ULSD - low but detectable toxicity on mysid growth (1.0 TU) and *Ceriodaphnia* reproduction (1.8 TUc) only.
- No unadditized Animalfat or Soy Biodiesel blends produced detectable toxicity to the mysid, topsmelt or fathead minnow.
- Animal Fat and Soy B-100 and B-20 mixtures caused toxicity to algae cell growth, abalone shell development, and *Ceriodaphnia* survival and/or growth.
- Except for algae, the additized Biodiesel B-20 test materials were substantially more toxic than the corresponding unadditized material.

Aquatic Chronic Toxicity Tests

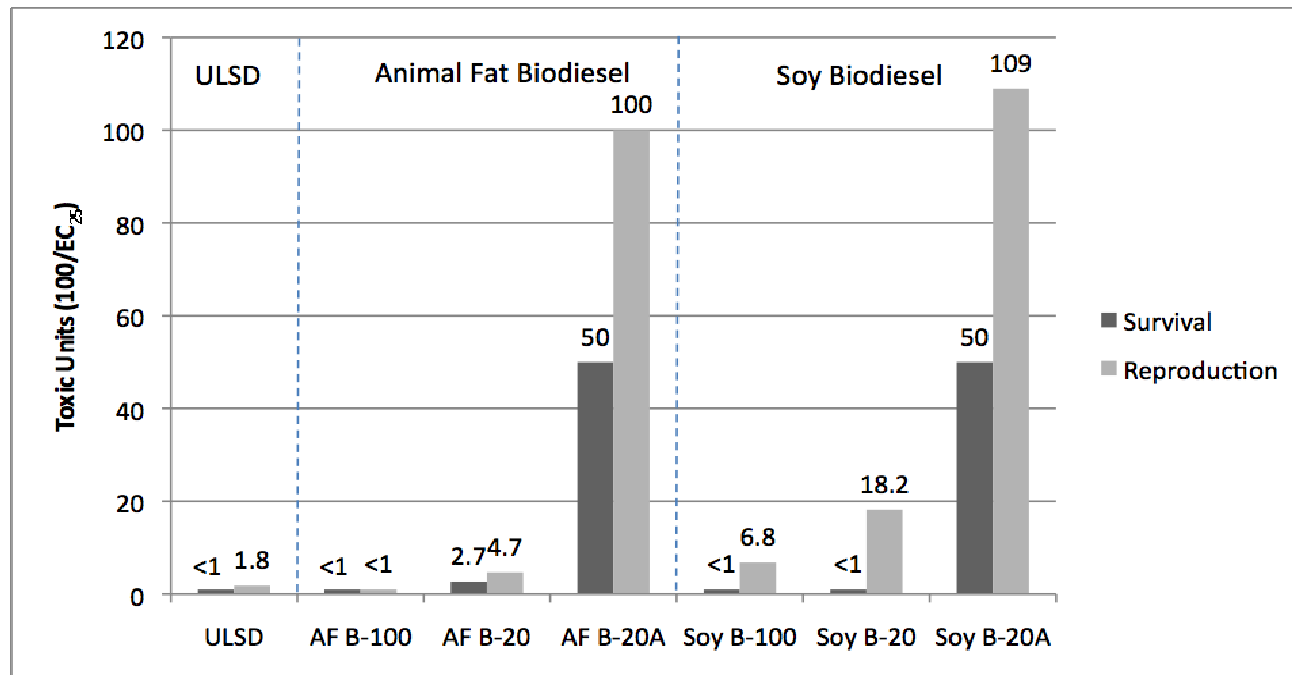
Examples



Red Abalone (*Haliotis Rufecens*) shell development

Aquatic Chronic Toxicity Tests

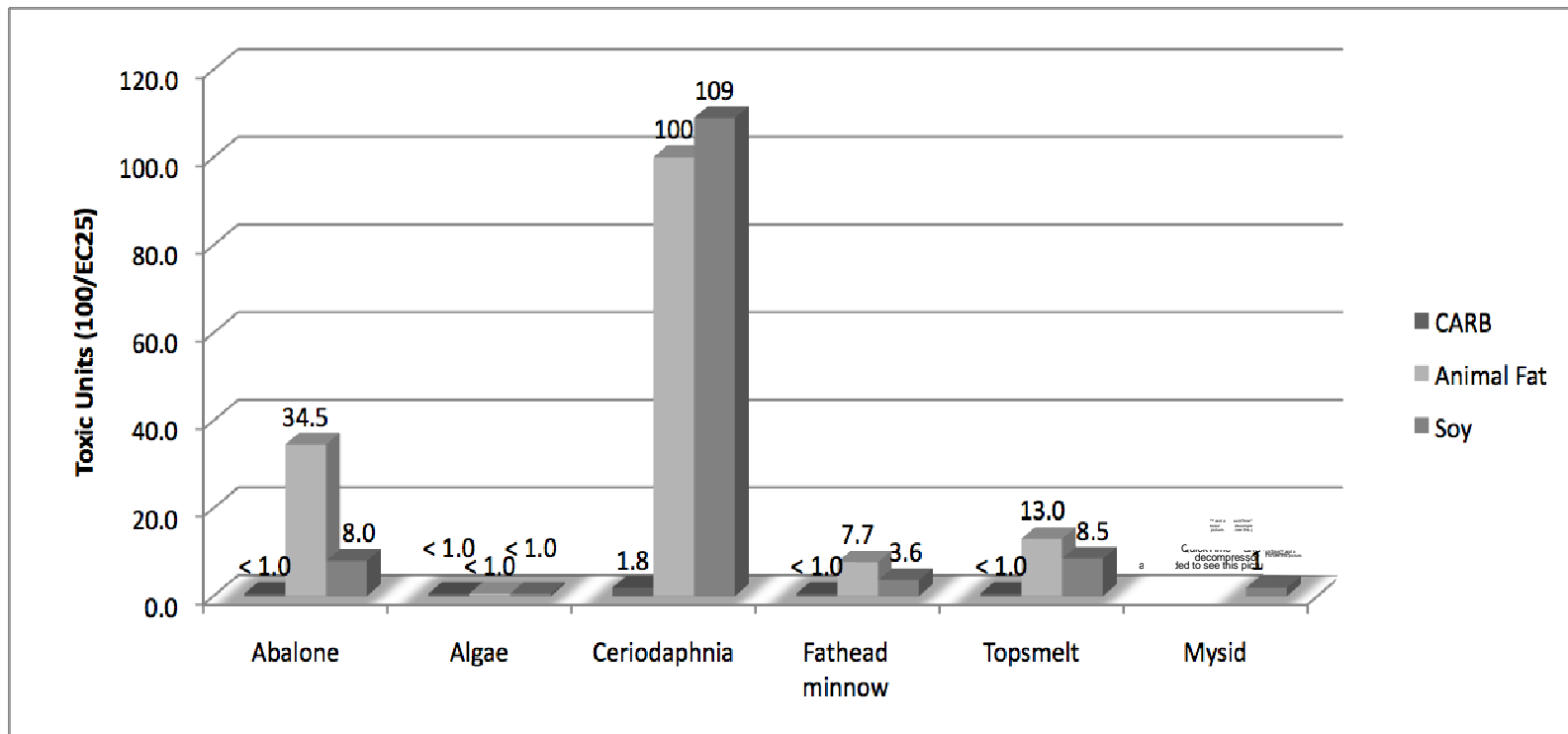
Examples



Water flea (*Ceriodaphnia dubia*) survival and reproduction

Aquatic Chronic Toxicity Tests

Summary Toxicity with additive



Toxicity apparent in all 6 species per growth endpoint

Aquatic Chronic Toxicity Tests

Summary Overall

- Biodiesel blends are significantly more toxic than CARB ULSD#2
 - algae cell growth
 - abalone shell development
 - *Ceriodaphnia* survival and growth
- Biodiesel 20% blends with antioxidant additive were substantially more toxic than the corresponding unadditized blend
 - abalone shell development
 - *Ceriodaphnia* survival and growth

Tier II for Biodiesel Blends Tested

Summary

- Mobility
 - AFB100a only shows smaller lens, more residual
- Biodegradation
 - All biodiesel blends more readily degradable than ULSD
 - Soy-based blends, or 20% s, somewhat more degradable
 - Additives effect are minor
- Aquatic Toxicity
 - Biodiesel blends are more toxic than ULSD#2
 - Biodiesel 20% blends with antioxidant additive are more toxic than the corresponding unadditized blend

Tier II for Biodiesel Blends Tested

Summary

- Mobility
 - AFB100a only shows smaller lens, more residual
- Biodegradation
 - All biodiesel blends more readily degradable than ULSD
 - Soy-based blends, or 20% s, somewhat more degradable
 - Additives effect are minor
- **Aquatic Toxicity**
 - **Biodiesel blends are more toxic than ULSD#2**
 - Biodiesel 20% blends with antioxidant additive are more toxic than the corresponding unadditized blend